Is there evidence for accelerated polyethylene wear in uncemented compared to cemented acetabular components? A systematic review of the literature

Hugo C. van der Veen · Hans-Peter W. van Jonbergen ·
Rudolf W. Poolman · Sjoerd K. Bulstra ·
Jos J. A. M. van Raay

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Abstract Joint arthroplasty registries show an increased rate of aseptic loosening in uncemented acetabular components as compared to cemented acetabular components. Since loosening is associated with particulate wear debris, we postulated that uncemented acetabular components demonstrate a higher polyethylene wear rate than cemented acetabular components in total hip arthroplasty. We performed a systematic review of the peer-reviewed literature, comparing the wear rate in uncemented and cemented acetabular components in total hip arthroplasty. Studies were identified using MEDLINE (PubMed), EMBASE and the Cochrane Central Register of Controlled Trials. Study quality was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach. The search resulted in 425 papers. After excluding duplicates and selection based on title and abstracts, nine studies were found eligible for further analysis: two randomised controlled trials, and seven observational studies. One randomised controlled trial found a

higher polyethylene wear rate in uncemented acetabular components, while the other found no differences. Three out of seven observational studies showed a higher polyethylene wear in uncemented acetabular component fixation; the other four studies did not show any differences in wear rates. The available evidence suggests that a higher annual wear rate may be encountered in uncemented acetabular components as compared to cemented components.

Introduction

Long-term survival in total hip arthroplasty (THA) is mainly determined by aseptic mechanical loosening. In Europe, aseptic loosening is the most common reason for revision in THA, followed by infection and recurrent dislocation [1]. The main factor in the process of this aseptic loosening is a chronic, granulomatous, inflammatory and potential osteolytic response that is induced by implant-derived wear particles [2]. In metal-to-polyethylene bearing couples, these wear particles mainly consist of polyethylene debris derived from the acetabular component. Submicron-sized particles especially lead to macrophage activation and a subsequent release of osteolytic mediators [3]. Polyethylene wear rate and the amount of particles released in a certain time period are directly related to osteolysis. Based on a review of the literature, it was suggested that radiographic wear rates of less than 0.1 mm/year were less likely lead to periprosthetic osteolysis [4].

Several factors may contribute to polyethylene wear, including patient's sex and activity level, femoral head diameter, and also component positioning and the quality of the polyethylene [5–7].

H. C. van der Veen (✉) · J. J. A. M. van Raay
Department of Orthopaedic Surgery, Martini Hospital,
P.O. Box 30.033, 9700 RM, Groningen, The Netherlands
e-mail: hcvanderveen@hotmail.com

H.-P. W. van Jonbergen
Department of Orthopaedic Surgery,
Deventer Hospital, Deventer, The Netherlands

R. W. Poolman
Department of Orthopaedic Surgery, Onze Lieve Vrouwe
Gasthuis, Amsterdam, The Netherlands

S. K. Bulstra
Department of Orthopaedic Surgery, University Medical Center
Groningen, Groningen, The Netherlands

Recent data from the Swedish Hip Arthroplasty Register (SHAR) show a higher rate of revision in uncemented acetabular components due to aseptic loosening, compared to cemented acetabular components [8]. This is in accordance with earlier reports on increased incidence of osteolysis in arthroplasties with uncemented acetabular components [9–11]. We therefore postulated that the wear rate of uncemented acetabular components is higher than the wear rate in cemented components. The purpose of our study was to systematically review the highest available evidence on the wear rate in both types of acetabular component fixation.

Materials and methods

A ‘PICOS’ was formulated in order to perform a systematic review and meta-analysis of the peer-reviewed literature [12]. We defined our population (P) as patients with primary or secondary osteoarthritis, treated by total hip arthroplasty (THA). The intervention (I) was defined as a THA with a cemented acetabular component. We compared (C) this intervention with a THA with an uncemented component, for the outcome (O) of wear rate (defined as mm/year or overall wear rate) of polyethylene. Study designs (S) were randomised controlled trials or cohort studies comparing both fixation methods of the acetabular component.

Inclusion criteria were specified in advance, and documented in an unpublished protocol. Randomised controlled trials or observational cohort studies comparing patients with cemented polyethylene acetabular components to patients with uncemented, metal-backed acetabular components were included. Furthermore, outcome had to be described as polyethylene wear rate in mm/year, mm³/year, or as overall wear rate. No language restrictions were used. Excluded were studies that assessed cemented metal-backed components or threaded cups, articulations other than metal-polyethylene, and studies with heterogenic populations and follow-up of less than three years.

Studies were identified using electronic databases searches in MEDLINE (PubMed) (1966 – January 3, 2012), EMBASE (1966 – January 3, 2012) and the Cochrane Central Register of Controlled Trials (January 3 2012). A medical librarian assisted in the search, using the following search terms with Boolean operators: “hip arthroplasty” OR “hip replacement” OR “hip prosthesis” AND (uncemented OR cementless OR “metal backed” OR shell OR cup OR socket OR “press fit”) AND (cemented OR cement) AND (polyethylene OR UHMWPE OR LDPE OR HDPE) AND wear. All reference lists of eligible articles were reviewed. Authors of eligible studies were contacted with regard to possible unpublished results or additional statistical data.

The systematic review was performed with adherence to the PRISMA statement [13]. Title and abstract were examined to assess their relevance (Fig. 1). Full articles were retrieved and assessed by two authors, using the prespecified inclusion and exclusion criteria. Disagreements between reviewers were resolved by consensus after discussion with a third reviewer trained in research methodology.

Relevant data regarding study design, study population, intervention and outcome measures (method of wear measurement) were extracted from the text, figures and tables of the articles included.

The quality of the included studies was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [14–16].

Results

A total of 425 papers were identified using the computerised database search. After removing 126 duplicates, 15 articles were included based on title. Abstracts of these articles were assessed, leading to nine eligible articles. Full-text analysis of these nine articles led to the exclusion of one study. The reason for exclusion of this study was: no direct comparison could be made between patients with cemented and uncemented acetabular components, because this was not defined as the primary aim of the study [17]. The authors were contacted, but no additional statistical data were available. After cross-referencing, one article could be added to the final result [18], leading to a total of nine articles eligible for qualitative synthesis (Fig. 1). Due to the heterogeneity of the study designs, study population and type of hip prosthesis, a meta-analysis was not performed. The following review of the literature is therefore descriptive. Studies included two randomised controlled trials [19, 20], and seven retrospective cohort studies [6, 18, 21–25]. The mean follow-up period ranged from five to more than 25 years. A total of 1,271 hips were included with a patient's mean age of 62 years (range 40–72 years). To assess the polyethylene wear of the acetabular component, one paper used radiostereometric analysis (RSA) [19], while the other eight studies used the Livermore method or modifications of the Livermore method. Using this method, on anteroposterior radiographs at follow-up, the shortest diameter of the polyethylene was measured from the centre of the femoral head, and this was compared to the distance at the same location on the initial postoperative radiograph [5]. In six studies, conventional polyethylene was used; three studies [20, 23, 25] used cross-linked polyethylene.

Study characteristics

Onsten and Carlsson used the RSA method to assess the amount of polyethylene wear in a randomised controlled

Fig. 1 PRISMA flow diagram.
PM PubMed; *EM* Embase;
CCR Cochrane Central Register
 of Controlled Trials

trial in 95 hips [19]. All patients received a cemented monobloc Charnley stem (DePuy International Ltd, Leeds, UK) with a 22 mm diameter stainless steel head. In 47 hips, a cemented Charnley polyethylene acetabular component was used (DePuy International Ltd, Leeds, UK), while in 48 hips, an uncemented metal-backed Harris-Galante type-I component (Zimmer, Warsaw, Indiana, USA) was used, with additional fixation using two to four screws. At five years of follow-up, no statistically significant differences in annual wear between groups were found (0.09 mm/year vs. 0.10 mm/year). For both cohorts, the type of polyethylene was not further specified, therefore creating a high probability of reporting bias. According to GRADE, the quality of this study is moderate.

McCombe and Williams used a prospective randomised trial to evaluate the annual wear rate in 115 hips [20]. A cemented stem (Exeter, Stryker Australia, Artarmon, Australia) was used in all hips with a 26 mm diameter head. One cohort with 52 hips had an uncemented metal-backed acetabular component (Duraloc 100, DePuy, Mount Waverley, Australia), and the second cohort with 63 hips had a cemented polyethylene acetabular component (Exeter, Stryker Australia). Mean radiological follow-up was 6.5 years, and polyethylene wear was assessed using a digitised Livermore method. In both cohorts, polyethylene had been machined and radiated in air. The uncemented group showed an annual wear rate of 0.15 mm/year, with 0.07 mm/year in the cemented group. This difference was

statistically significant ($p < 0.0001$). According to GRADE, the quality of this study is high.

A further seven retrospective studies reported the wear rate of uncemented and cemented acetabular components [6, 18, 21–25]. Only three of these studies reported statistical methods; one study observed a lower annual wear rate in cemented acetabular components [25] and two found no difference in wear rate [23, 24]. The remaining four studies did not provide a statistical analysis of the data. Two studies reported a lower wear rate in cemented components as compared to uncemented components [6, 22], and the other two studies found no difference [18, 21]. All these retrospective studies used the Livermore method or modifications thereof. The quality of these retrospective studies according to GRADE is low to very low (Table 1).

Discussion

Only one high quality study was included in our systematic review, demonstrating an increased wear rate in uncemented metal-backed components (Duraloc) versus cemented acetabular components (Exeter) [20]. One moderate quality study showed no difference between cemented acetabular components (Charnley) and uncemented metal-backed components (Harris-Galante type-I) [19]. Three out of seven low to very low quality retrospective studies reported a higher wear rate in uncemented acetabular components [6, 22, 25].

Table 1 Grading of Recommendations Assessment, Development and Evaluation (GRADE) table of studies analysed

A	B	C	D	E	F	G	H	I	J	K	L
Nashed et al. (1995)	O	No	No	No	No	U	24	15		L	(+)
Callaghan et al. (1995)	O	No	No	No	No	D**	104	63		VL	(+)
Onsten et al. (1998)	RCT	Yes [#]	No	No	No	U	47	48	Cement vs. uncemented: 0.09 vs. 0.10 mm/year (CI95% -0.01–0.03)	M	(+)
Clohisy et al. (2001)	MO	No	No	No	No	U	45	45		L	(+)
Gaffey et al. (2004)	O	No	No	No	No	D**	471	70		VL	(+)
McCombe et al. (2004)	RCT	No	No	No	No	U	63	52	Cement vs. uncemented: 0.07 vs. 0.15 mm/year ($p<0.0001$)	H	+
Hartofilakidis et al. (2009)	O	No	No	No	No	U	50	51		L	(+)
Bjerkholt et al. (2010)	O	No	No	No	No	U	62	30		L	(+)
Kampa et al. (2010)	MO	Yes*	No	No	No	U	15	15		L	(+)

A. Author (publication year)

B. Design

RCT: randomised controlled trial

O: observational

MO: matched case control, observational

C. Limitations

No: no serious limitations

Yes: serious limitations

[#] polyethylene (PE) not specified for both cohorts

* 5 bilateral hips ceramic-PE articulation

D. Inconsistency

No: no serious inconsistency

E. Indirectness

No: no serious indirectness

F. Imprecision

No: no serious imprecision

G. Publication bias

U = undetected

D = detected

** In part same cohorts

H. Number of treated patients (cemented acetabular component)

I. Number of controls (uncemented acetabular component)

J. Effect (annual wear rate mm/year)

K. Quality

H: high

M: moderate

L: low

VL: very low

L. Recommendation

(+: Weak for

+: Strong for

Fixation of acetabular components and polyethylene (PE) wear in patients with primary or secondary osteoarthritis of the hip

Population: patients with primary or secondary osteoarthritis treated with a total hip arthroplasty (THA)

Intervention: THA with a cemented acetabular component

Comparison: THA with an uncemented acetabular component

Outcome: wear rate (mm/year or overall wear rate) of PE

Our systematic review is the first to specifically review the available evidence regarding the possible influence of acetabular component fixation on the wear rate of polyethylene. In order to obtain an evidence-based assessment of the available literature on this subject, we performed our review with adherence to the PRISMA statement and used the GRADE approach. No language restrictions were used, and, if necessary, authors were contacted for unpublished results or additional statistical data. However, our review is limited in that no meta-analysis was performed due to clinical heterogeneity. Furthermore, only two randomised controlled trials were identified; one study used the RSA method, and the other used a digitised Livermore method to assess polyethylene wear [19, 20]. Several confounding factors could have influenced the outcome especially for the retrospective cohort studies. First, authors did not always mention the type of polyethylene used, even in the RCT performed by Onsten and Carlsson [19]. Second, other wear influencing factors, such as cup positioning and patient's activity level, not always were reported. Another limitation is that the mean follow-up in the studies included varied from five years to more than 25 years. This resulted in studies describing the results of obsolete fixation methods of the acetabular component. Both fixation with additional screws and openings in the metal shell are considered risk factors for wear and osteolysis [6, 26].

The Swedish Hip Arthroplasty Register reported a higher rate of revision in uncemented acetabular components due to aseptic loosening, compared to cemented acetabular components, probably resulting from wear-related problems [8]. Increased revision rates were also reported by the Norwegian Arthroplasty Register in the medium-term to long-term follow-up, attributed to wear and osteolysis in modular metal-backed acetabular components. These higher revision rates mostly occurred after seven years [27]. The Finnish Arthroplasty Register showed no important differences in survival rates for aseptic loosening between cemented and uncemented acetabular components. However, further analysis of these registry data showed that numerous revisions of the modular uncemented acetabular components were due to excessive wear of the polyethylene liner [28].

Although registry data do not aim to establish causality [29], increased wear properties of uncemented acetabular components are suggested. This assumed increase in polyethylene wear in uncemented acetabular components can be considered a multifactorial entity. Differences in load transfer due to an absent cement interface, or micromovements of modular polyethylene inserts in metal acetabular components, could lead to this higher wear rate [18, 24]. Poor fit of polyethylene inserts and metal shells due to technical failure of the locking mechanism might also play a role. Furthermore, thinner polyethylene liners used in uncemented sockets, leading to increased contact stresses, may contribute as well. The evidence on this, however, is not

straightforward [30–32]. Another theoretical explanation for increased wear rates in press-fit acetabular components could be their less forgiving positioning during implantation, leading to edge loading. This might be prevented in cemented acetabular components, due to a more correctable positioning during implantation.

Two recent systematic reviews [33, 34] comparing cemented and uncemented THA addressed acetabular fixation types in a broader perspective than our review. Pakvis and van Hellemondts reviewed both the clinical and radiological outcome and postulated that the surgeon should choose an established cemented or uncemented acetabular component based on patient characteristics, knowledge, experience and preference [33]. However, Clement and Biant concluded that cemented acetabular fixation may be the gold standard in total hip arthroplasty, based primarily on the lower overall re-operation risk for cemented fixation [34]. In agreement with our findings, both reviews reported an equal or increased articular wear rate with uncemented fixation.

The weakest link in contemporary total hip arthroplasty seems to be the acetabular component. The results of this systematic review suggest a negative influence of uncemented acetabular component fixation on polyethylene wear rate, and are in favour of cementation of the acetabular component. Next to acetabular component cementation, polyethylene itself also plays an important role in improving wear properties. Highly cross-linked polyethylene has shown an excellent medium-term performance [35, 36]. Nowadays, second generation highly cross-linked polyethylenes have been developed with even more wear resistance (eg X3 [Stryker Orthopedics, Mahwah, New Jersey, USA], ArCom XL and E-Poly [Biomet Orthopedics, Warsaw, New Jersey, USA]), showing promising in vitro results [4, 37, 38]. Future research should focus on high quality clinical trials prospectively investigating arthroplasties with cemented acetabular components, in combination with second generation highly cross-linked polyethylene. Because of its ability to address early wear, ideally RSA should be used. However, use of this method is limited because of its relative expense and required expertise. Next to RSA, computer-assisted edge-detection techniques offer improved accuracy in especially the intermediate to long-term follow-up, and are generally more readily available [39].

In conclusion, the results of this systematic review of the available evidence suggest that a higher annual wear rate of polyethylene may be encountered in uncemented acetabular components as compared to cemented components. Future high quality studies should focus on cemented acetabular components combined with second generation highly cross-linked polyethylene.

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Conflict of Interest The authors declare that they have no conflict of interest.

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